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H4D
G1G
G3N
Selected US specifications from IPC sub-classes
G01S B66C B61L B63B

(54) Avoiding collision between cranes

(57) A system for avoiding collision between two mobile objects which run substantially on a single running path for example cranes running on a track measures the distance between the mobile objects. The respective brake stopping distances of the objects are estimated on the basis of their running speeds and alarm signals for stopping the mobile objects are given to the mobile objects when the sum of the respective braking stopping distances of the two objects is greater than the distance between the objects. The space between the objects may be measured, for example, by triangulation or cw ranging using light.

FIG. 1

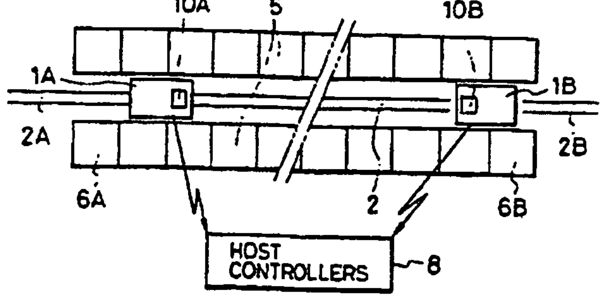

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FIG. 1

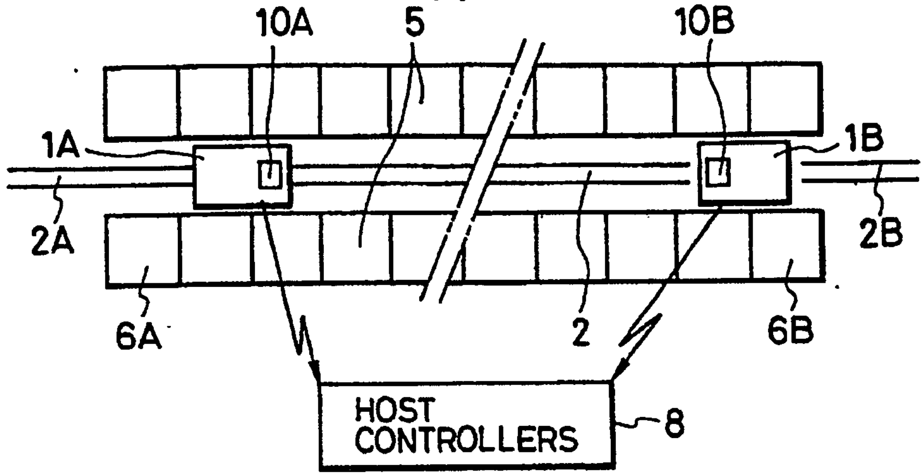
10A
5
10B
1A
1B
2A
2B
6A
2
6B
HOST CONTROLLERS
8

FIG. 2

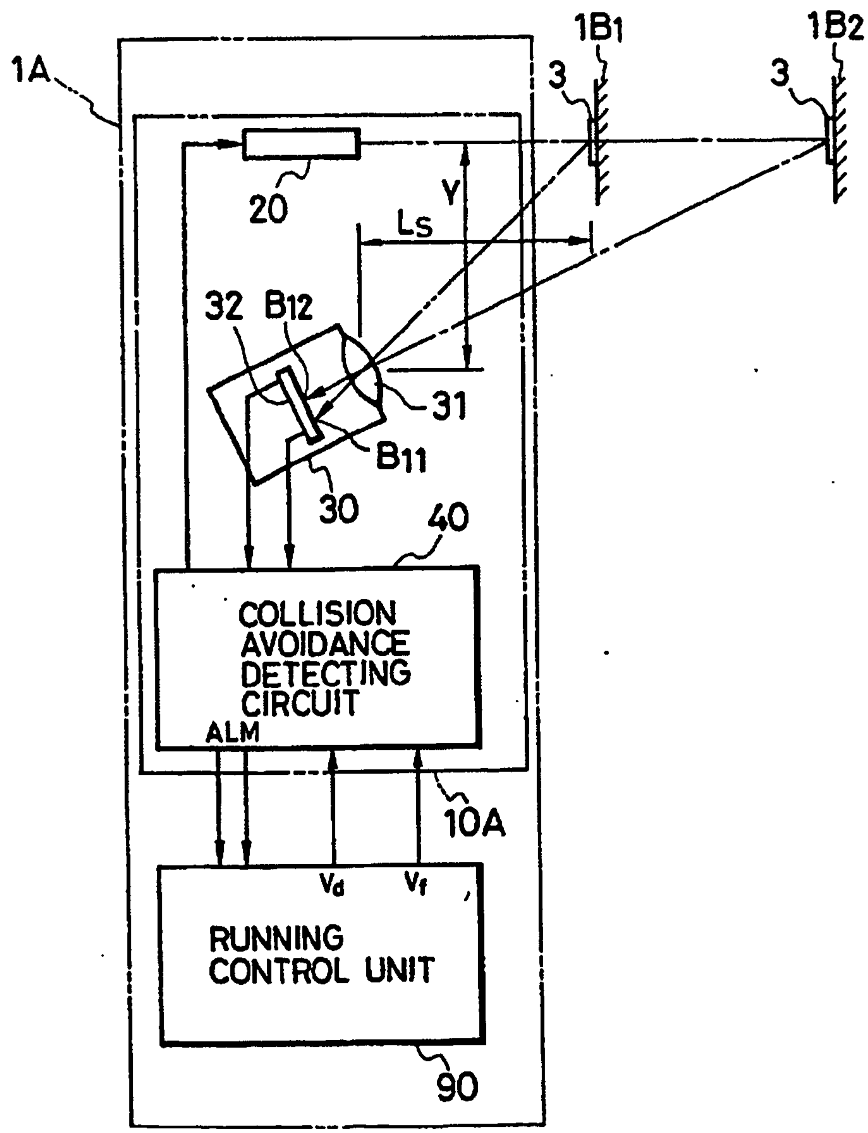
1B1
1B2
1A
3
3
20
Y
Ls
32
B12
31
B11
30
40
COLLISION AVOIDANCE DETECTING CIRCUIT
ALM
10A
Vd
Vf
RUNNING CONTROL UNIT
90

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FIG. 3

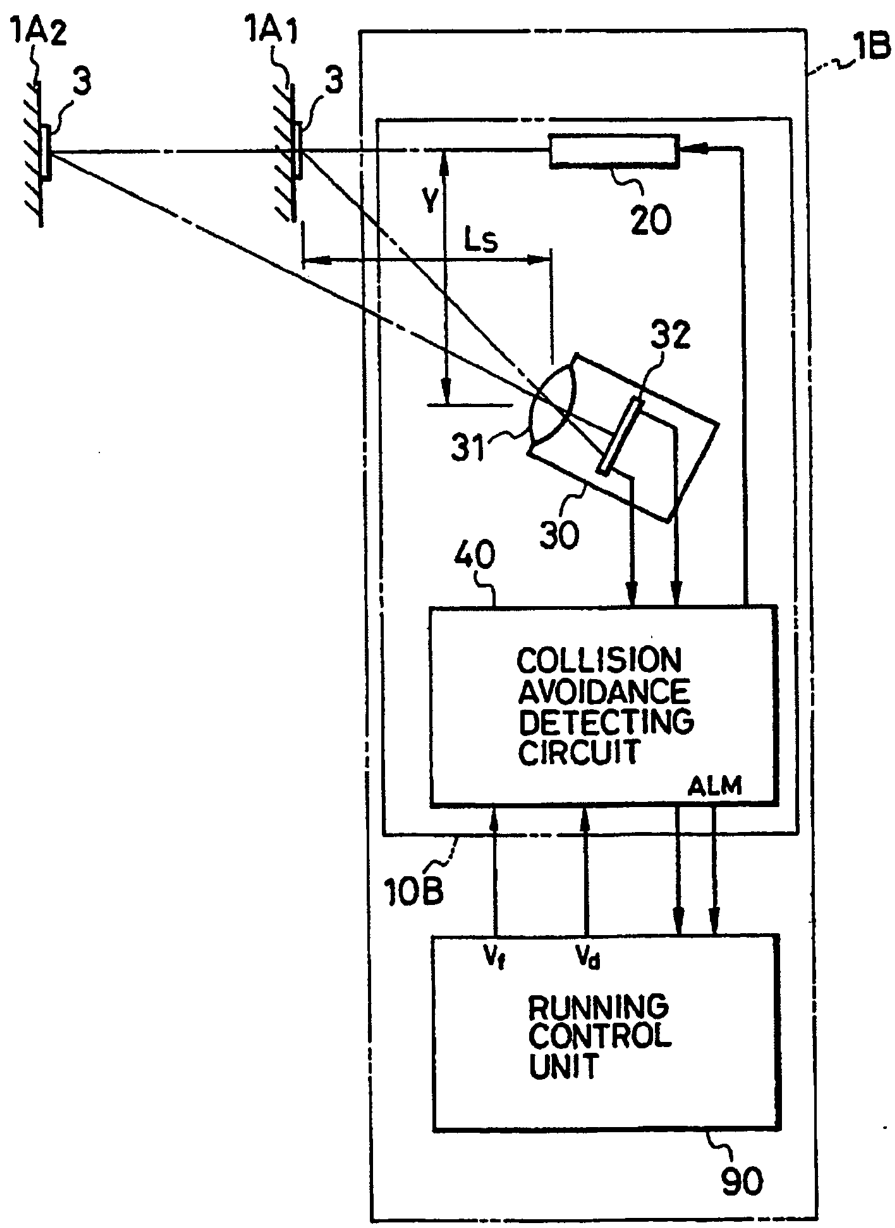

FIG. 4

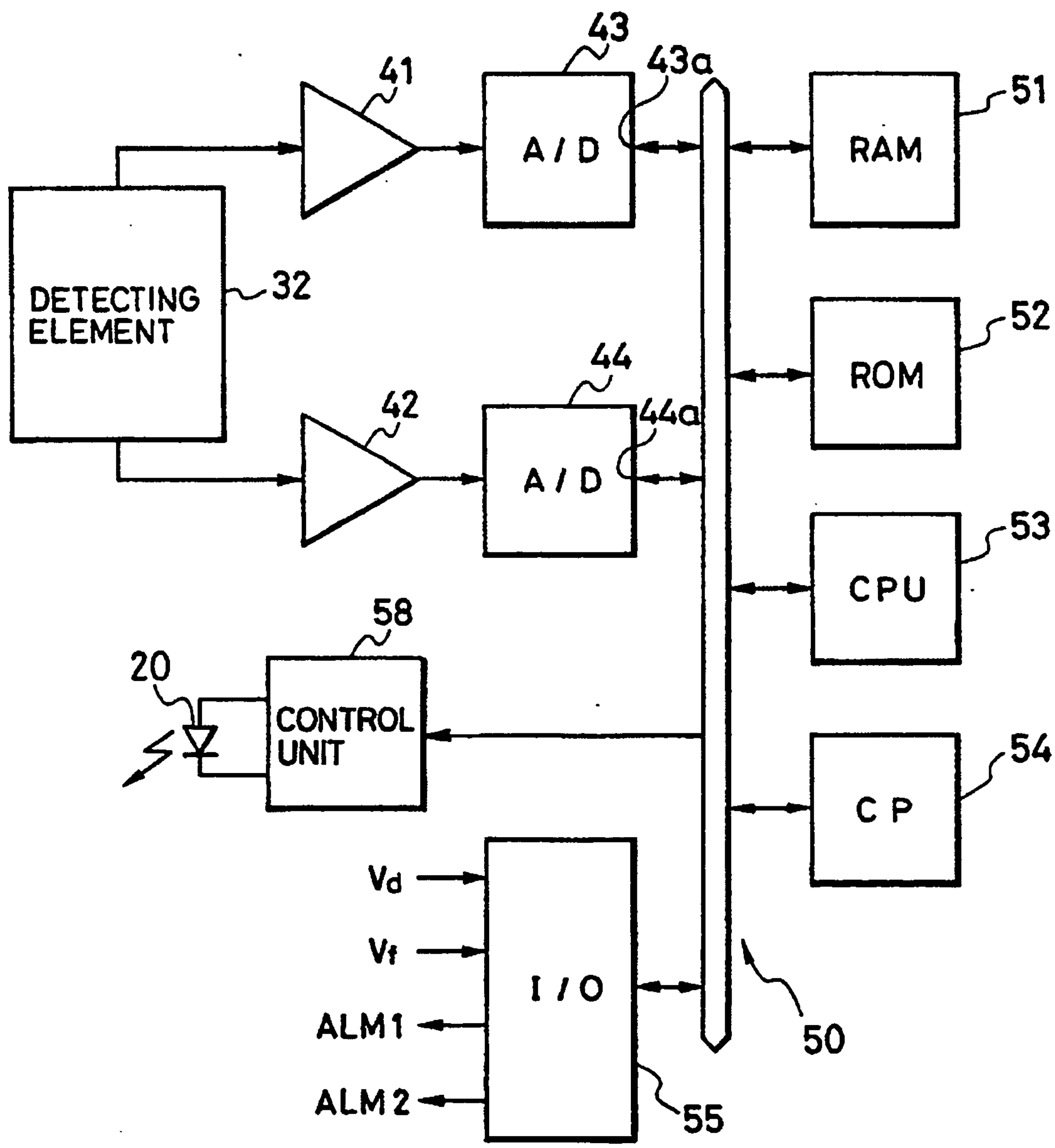
DETECTING ELEMENT
32
41
42
43
43a
A / D
44
44a
A / D
RAM
51
ROM
52
CPU
53
C P
54
58
20
CONTROL UNIT
Vd
Vf
ALM1
ALM2
I / O
55
50

FIG. 5

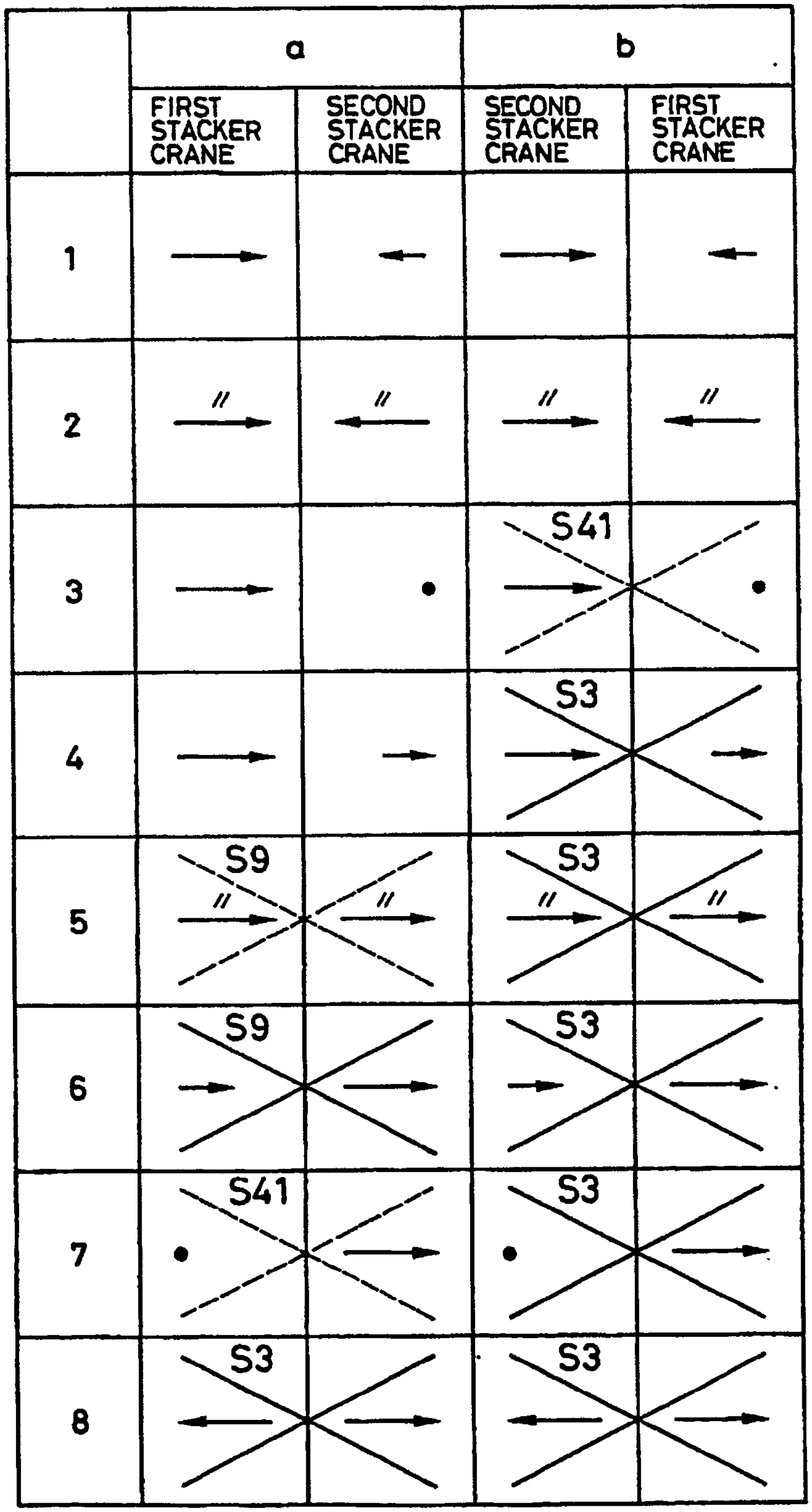
a
b
FIRST STACKER CRANE
SECOND STACKER CRANE
SECOND STACKER CRANE
FIRST STACKER CRANE
1
2
3
4
5
6
7
8
S41
S3
S9
S3
S9
S3
S41
S3
S3
S3

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FIG. 6

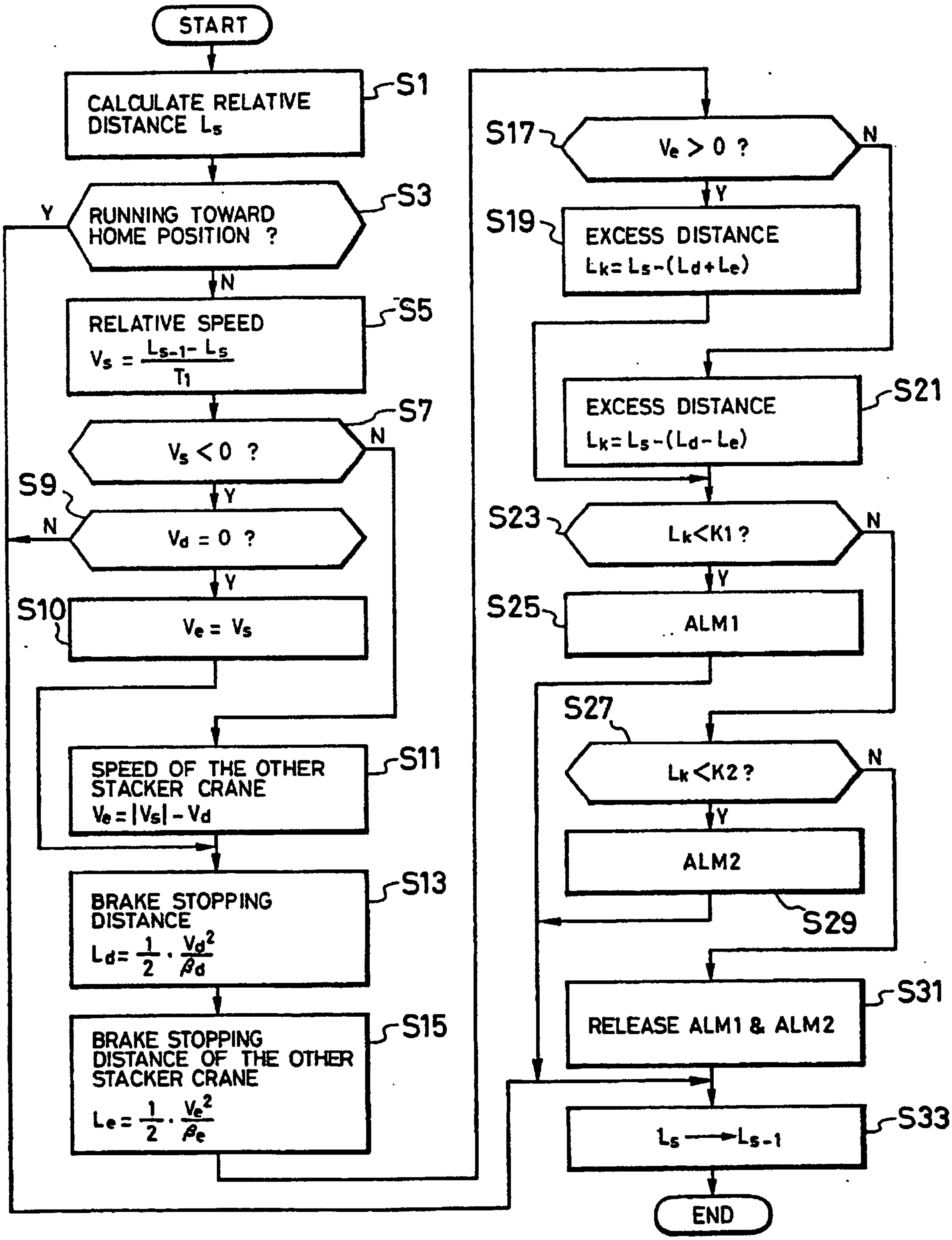

FIG. 7

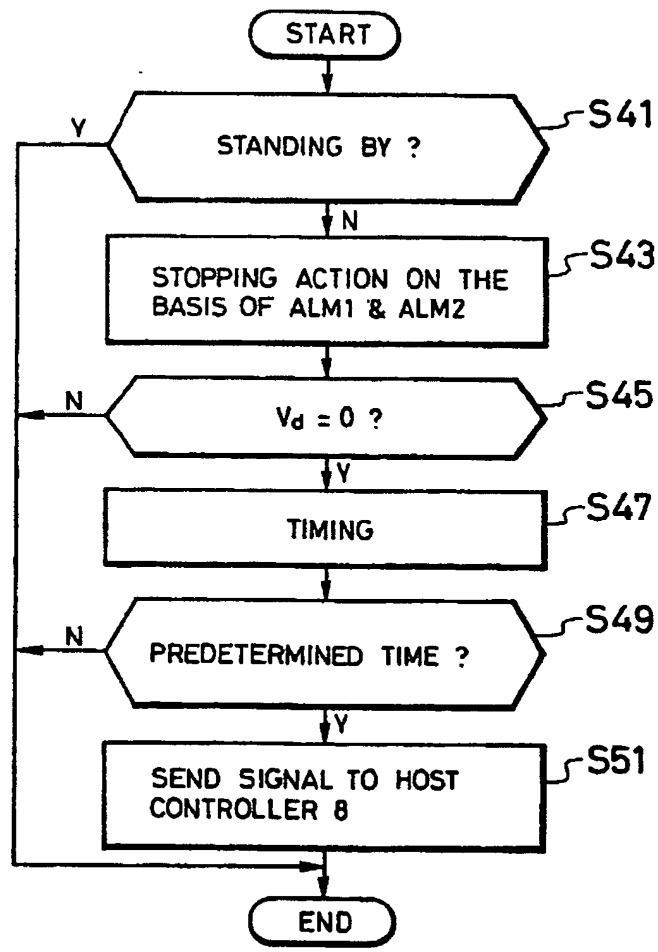
START
STANDING BY ?
S41
Y
N
STOPPING ACTION ON THE BASIS OF ALM1 & ALM2
S43
Vd = 0 ?
S45
N
Y
TIMING
S47
PREDETERMINED TIME ?
S49
N
Y
SEND SIGNAL TO HOST CONTROLLER 8
S51
END

FIG. 8

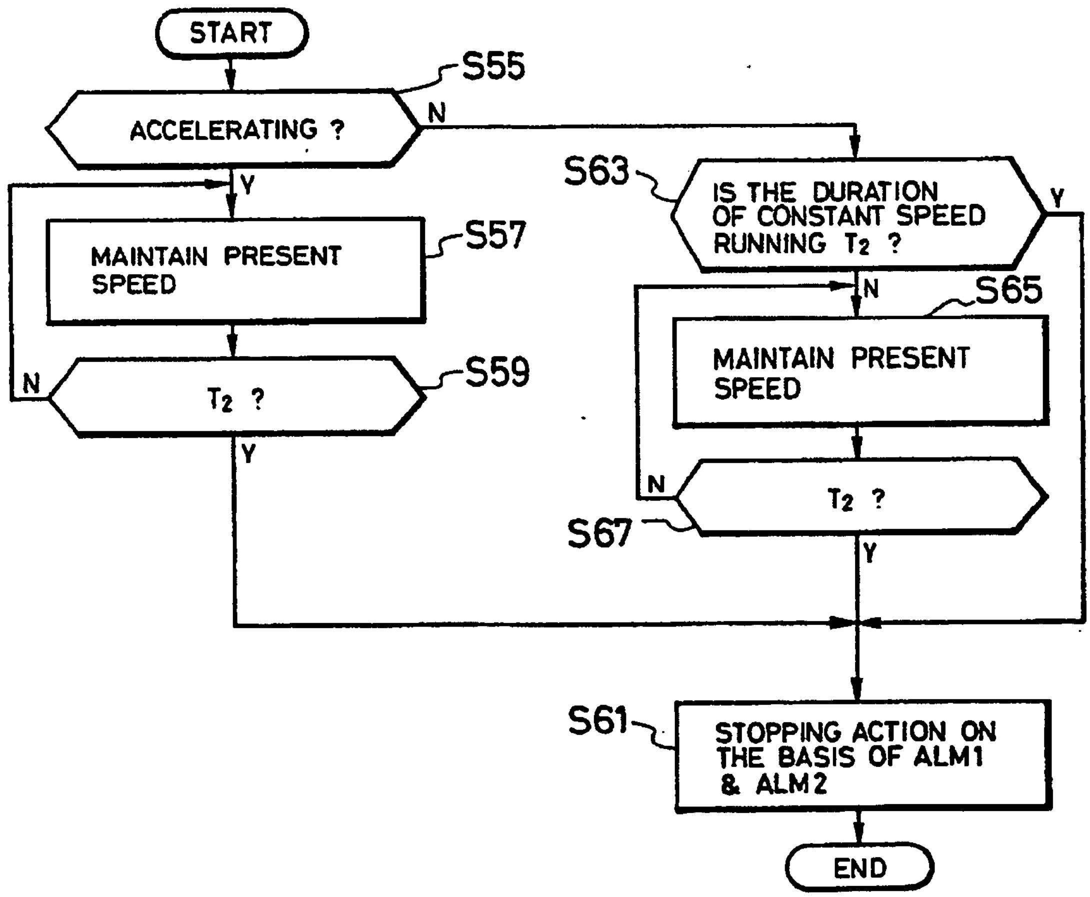
START
S55
ACCELERATING ?
N
Y
S57
MAINTAIN PRESENT SPEED
S59
N
T2 ?
Y
S63
IS THE DURATION OF CONSTANT SPEED RUNNING T2 ?
Y
N
S65
MAINTAIN PRESENT SPEED
N
T2 ?
S67
Y
S61
STOPPING ACTION ON THE BASIS OF ALM1 & ALM2
END

FIG. 9

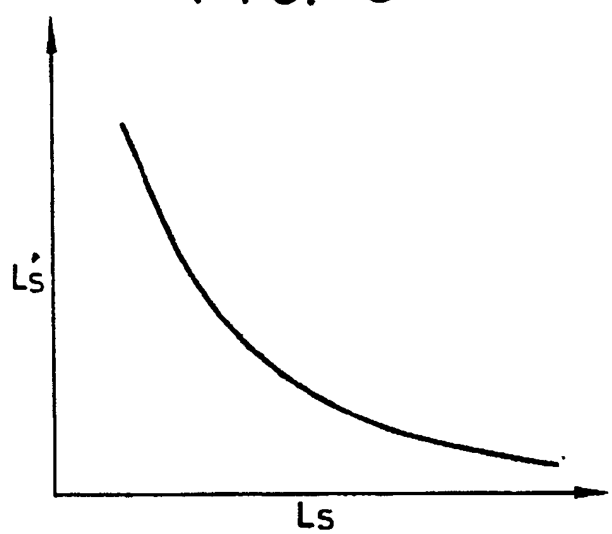

FIG. 10

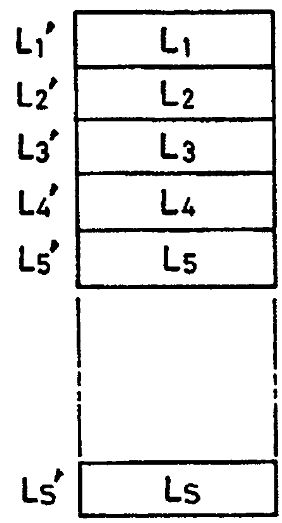

FIG. 11

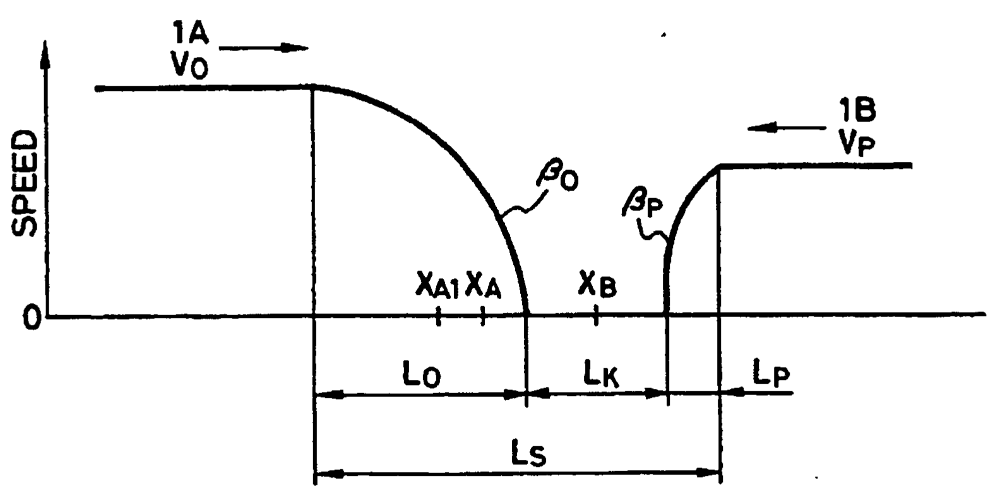

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FIG. 12

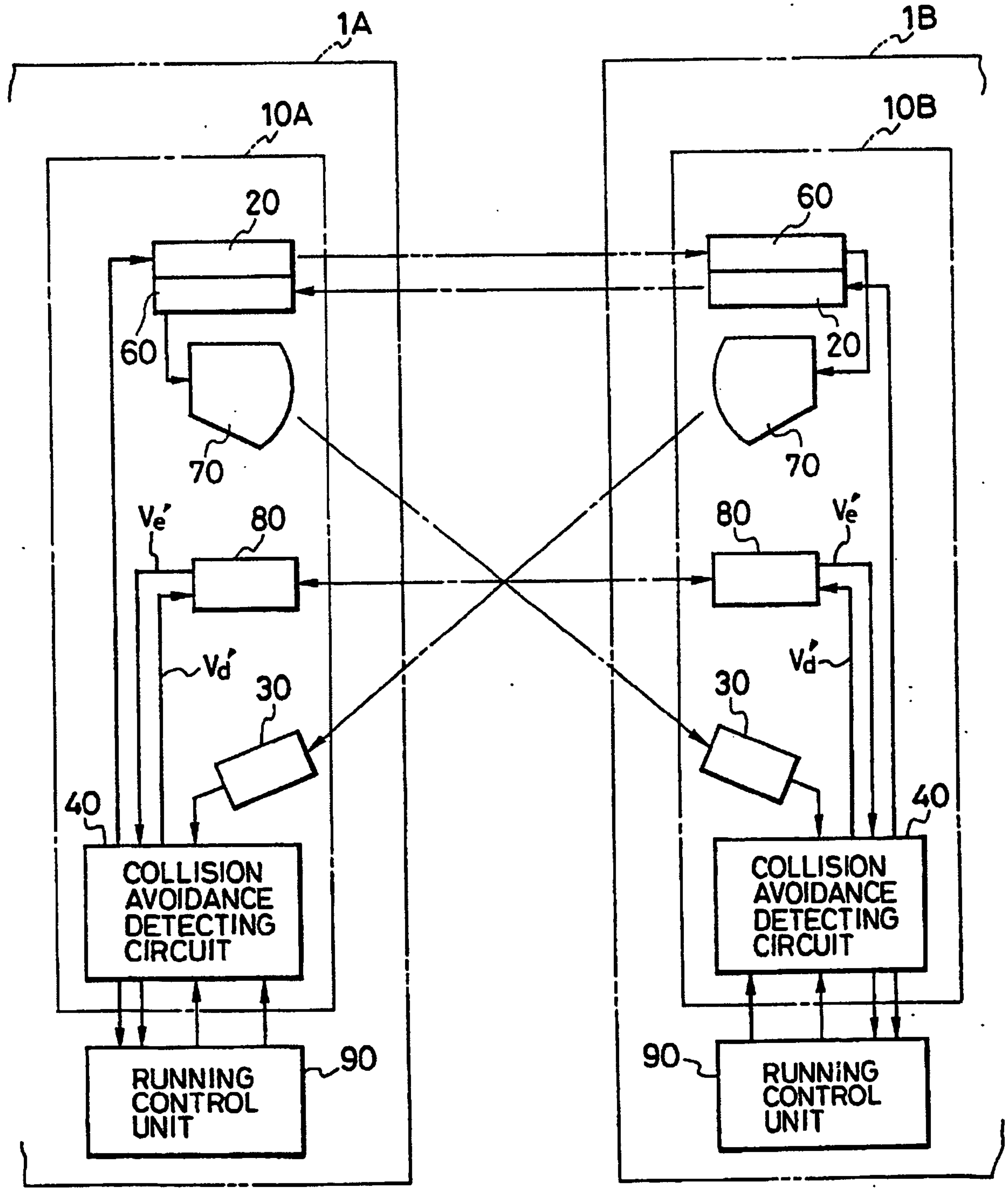
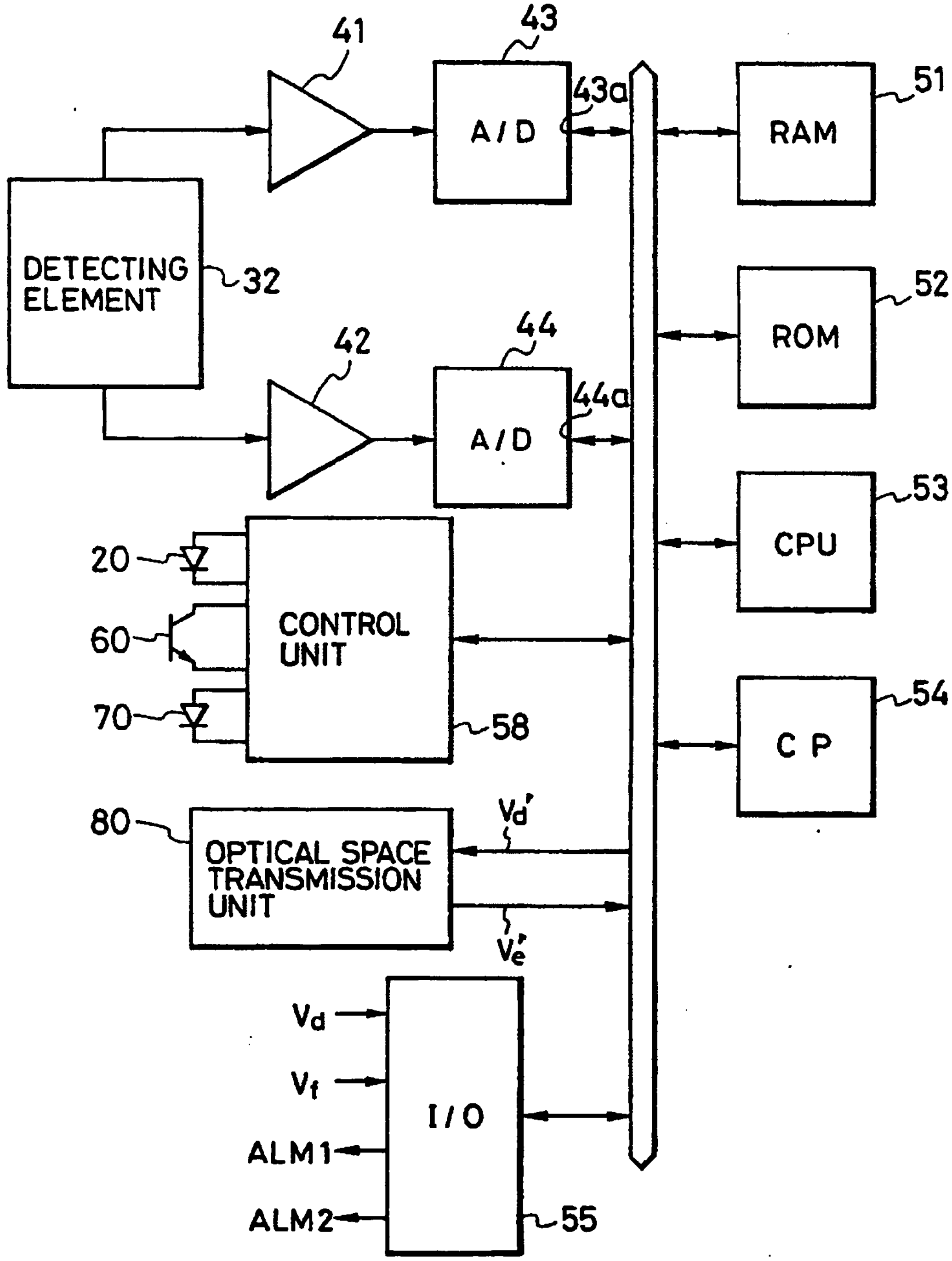


FIG. 13



41
43
43a
51
RAM
A / D
DETECTING ELEMENT
32
52
ROM
42
44
44a
A / D
53
CPU
20
60
70
CONTROL UNIT
58
54
C P
80
OPTICAL SPACE TRANSMISSION UNIT
Vd'
Ve'
Vd
Vf
ALM1
ALM2
I / O
55

FIG. 14

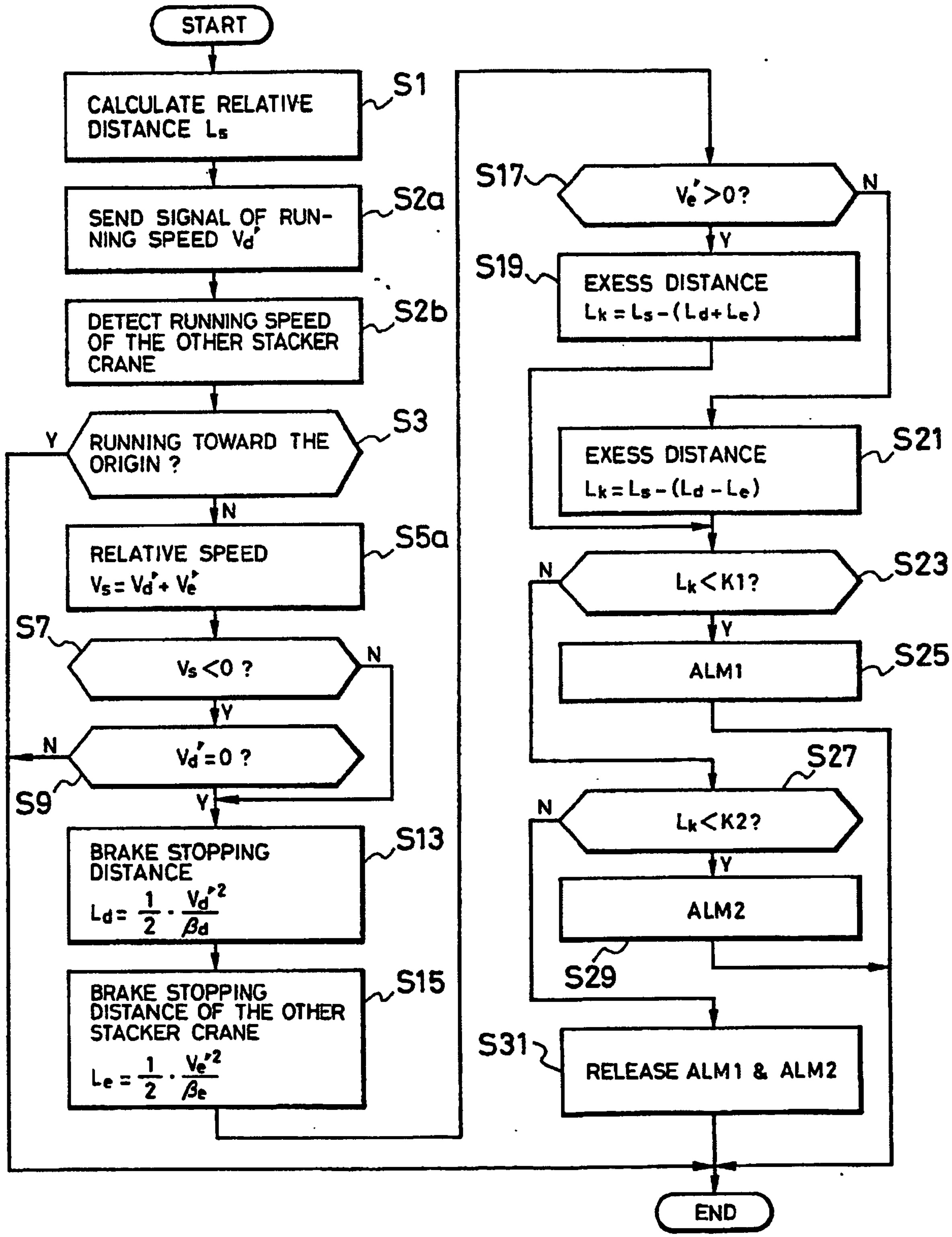

START
CALCULATE RELATIVE DISTANCE L_s
S1
SEND SIGNAL OF RUNNING SPEED V_d'
S2a
DETECT RUNNING SPEED OF THE OTHER STACKER CRANE
S2b
RUNNING TOWARD THE ORIGIN ?
S3
Y
N
RELATIVE SPEED $V_s = V_d' + V_e'$
S5a
S7
$V_s < 0$?
N
Y
$V_d' = 0$?
N
S9
Y
BRAKE STOPPING DISTANCE $L_d = \frac{1}{2} \cdot \frac{V_d'^2}{\beta_d}$
S13
BRAKE STOPPING DISTANCE OF THE OTHER STACKER CRANE $L_e = \frac{1}{2} \cdot \frac{V_e'^2}{\beta_e}$
S15
S17
$V_e' > 0$?
N
Y
S19
EXESS DISTANCE $L_k = L_s - (L_d + L_e)$
EXESS DISTANCE $L_k = L_s - (L_d - L_e)$
S21
N
$L_k < K1$?
S23
Y
ALM1
S25
S27
N
$L_k < K2$?
Y
ALM2
S29
S31
RELEASE ALM1 & ALM2
END

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FIG. 15

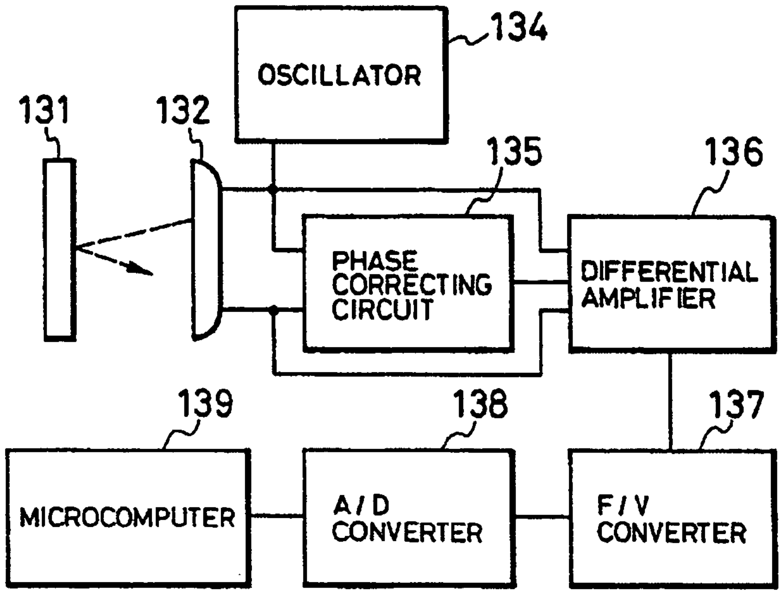


FIG. 16

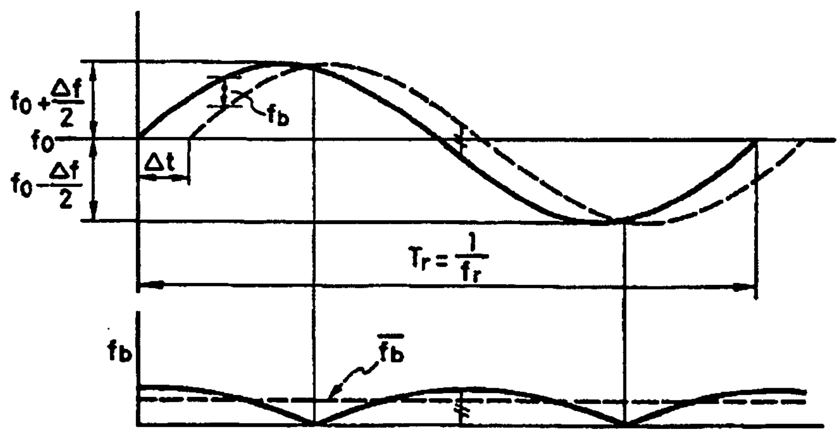
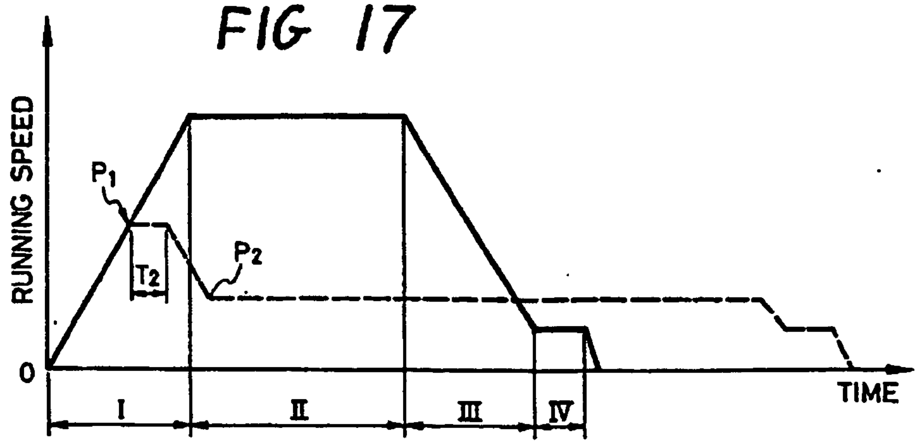


FIG 17



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SPECIFICATION

METHOD AND SYSTEM FOR AVOIDING COLLISION BETWEEN MOBILE OBJECTS

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a method of avoiding collision between two mobile objects which run substantially on a single running path, and a system for carrying out the same.

Description of the Prior Art

Overhead traveling cranes installed in a factory, stacker cranes operating in an automatic warehouse, and operatorless platform trucks which run on the ground are exemplary mobile objects which run substantially on a single running path.

Overhead traveling cranes are operated by operators for cargo working operation so that the overhead traveling cranes will not collide with each other.

Stacker cranes operate in an automatic warehouse automatically under the control of a controller installed on the floor. The controller monitors the respective positions of the stacker cranes and gives instructions to the stacker cranes as to possible running position so that the stacker

cranes will not collide with each other during cargo working opertion. (Japanese Patent Provisional Publication (Kokai) No. 59-48305)

Thus, instructions are given automatically or manually to the mobile objects so that the mobile objects will not collide with each other. However, it is possible that the mobile objects collide with each other when incorrect instructions are given or when the controller malfunctions. To avoid such accidental collision of the mobile objects, the mobile objects are provided with a collision avoidance system which monitors the distance between the two mobile objects and stops the mobile objects when the distance is reduced below a predetermined distance.

Japanese Patent Publication No. 57-237 discloses collision avoidance systems using light rays. In one of the collision avoidance systems a light projector for projecting a light beam, and a light receiver for receiving light are provided on each of two mobile cranes at an inclination to the running direction of the mobile cranes so that the light beam projected by the light projector of one of the two mobile crane is received by the light receiver of the other mobile crane when the interval between the two mobile cranes is reduced below a predetermined distance. Thus, the mobile cranes are stopped when the interval between the two mobile cranes is reduced below the predetermined distance. In

another collision avoidance system disclosed in Japanese Patent Publication No. 57-237, a light projector and a light receiver are provided on each of two mobile cranes in alignment with the running direction of the mobile cranes so that the light receiver of one of the mobile cranes receives light projected by the light projector of the other mobile crane while the interval between the two mobile cranes is greater than a predetermined distance and the light receiver of one of the mobile cranes does not receive light projected by the other mobile crane when the interval between the two mobile cranes is reduced below the predetermined distance. Thus, the mobile cranes are stopped when the interval therebetween is reduced below the predetermined distance.

Japanese Patent Publication No. 55-316 discloses a wire collision avoidance system, in which two induction lines are extended along the running path of mobile cranes, each mobile crane is provided with a transmitting antenna and a receiving antenna, each mobile crane transmits a signal of a specific frequency, and the transmitting antennas and the receiving antennas are associated with the induction lines by inductive coupling. When the interval between the two mobile cranes is reduced below a predetermined distance, the receiving antenna of one of the two mobile cranes receives the signal transmitted through the transmitting antenna of the other to detect the

interval between the mobile cranes. When the interval between the two mobile cranes is smaller than the predetermined distance, alarm signal is generated.

Japanese Patent Publication No. 59-40748 discloses a collision avoidance system employing microwaves highly capable of rectilinear propagation as distance detecting means.

According to the foregoing prior art, only a single predetermined distance is determined as a reference for deciding whether or not the mobile cranes are to be stopped and whether or not an alarm is to be generated. This predetermined distance is determined so that the two mobile cranes running at the maximum speed toward each other will not collide with each other when braked for stopping upon the detection of the reduction of the interval therebetween to the predetermined distance. Accordingly, the predetermined distance varies according to the variation of the maximum speed of the mobile objects such as stacker cranes. Therefore, the ratio of a period in which two mobile objects capable of running at a comparatively high running speed relative to the length of the running path, such as overhead traveling cranes and stacker cranes, is allowed to run at the maximum speed to a total operating period is small. Furthermore, when two mobile objects are running respectively toward objective positions located between the two mobile

objects and the respective running speeds of the two mobile objects are reduced to stop the two mobile objects respectively at the objective positions, the two mobile objects are braked to stop when the interval between the two mobile objects is reduced below the predetermined distance determined on the basis of the maximum running speed.

Suppose that two stacker cranes are operated in an automatic warehouse. In most cases, the automatic warehouse has a doorway for one of the two stacker cranes on one end of a running path and a doorway for the other stacker crane on the other end of the running path. It often occurs that the interval between the two stacker cranes becomes smaller than the predetermined distance when both the two stacker cranes are running in one direction. In such a case, the predetermined distance may be a small distance and it is necessary to stop only the following stacker crane.

As obvious from the foregoing description, since the predetermined distance is determined on the basis of the maximum speed of the mobile objects in the conventional collision avoidance system, the ratio of a period in which the mobile objects are allowed to run at the maximum speed to a total operating period is small, and thereby the cargo working efficiency of the mobile objects is deteriorated.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide a method of avoiding the collision of mobile objects and a system for carrying out the same capable of improving the cargo working efficiency of the mobile objects.

According to the present invention, the interval between two mobile objects is measured, the respective brake stopping distances of the two mobile objects are estimated on the basis of the respective present running speed of the two mobile objects, and alarm signals for stopping the two mobile objects are given to the mobile objects when the sum of the respective brake stopping distances of the two mobile objects is greater than a distance determined on the basis of the present interval between the mobile objects.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the present invention will become apparent from the following description taken in conjunction with the accompanying drawings, in which:

Figure 1 is a diagrammatic illustration showing the constitution of an automatic warehouse incorporating a collision avoidance system, in a preferred embodiment, according to the present invention;

Figure 2 is a block diagram of a collision avoidance system, in a first embodiment, according to the present invention;

Figure 3 is a block diagram of a collision avoidance system embodying the present invention;

Figure 4 is a block diagram of a detecting circuit incorporated into the collision avoidance system Fig. 2;

Figure 5 is a table of assistance in explaining combinations of the respective running modes of two stacker cranes in terms of running speed and running direction;

Figure 6 is a flow chart of a showing the operating procedure of the collision avoidance system of Fig. 2;

Figure 7 is a flow chart showing the operating procedure of a running mode controller embodying the present invention;

Figure 8 is a flow chart showing the operating procedure of a running mode controller embodying the present invention;

Figure 9 is a graph showing the relation between light receiving position and relative distance;

Figure 10 is a correction table for correcting the relation between light receiving position and relative distance;

Figure 11 is a diagram of assistance in explaining a mode of stopping a stacker crane;

Figure 12 is a block diagram of a collision avoidance system, in a second embodiment, according to the present invention;

Figure 13 is a block diagram of a detecting circuit incorporated into the collision avoidance system of Fig. 12;

Figure 14 is a flow chart showing the operating procedure of the collision avoidance system of Fig. 12;

Figure 15 is a block diagram of a distance measuring unit embodying the present invention;

Figure 16 is a diagram of assistance in explaining the characteristics of microwaves; and

Figure 17 is diagram showing a running pattern.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A collision avoidance system, in a first embodiment, according to the present invention as applied to stacker cranes to be operated in an automatic warehouse will be described hereinafter with reference to Figs. 1 to 10.

Referring to Fig. 1, an automatic warehouse is provided with a rail 2 extended along a running path, and two stacker cranes, namely, a first stacker crane 1A and a second stacker crane 1B which run along the rail 2. Storage racks 5 having a plurality of shelves are installed respectively on the opposite sides of the running path. The warehouse has a first doorway 6A for the stacker crane 1A, namely, the first stacker crane 1A

at one end of the running path, and a second doorway 6B for the second stacker crane 1B at the other end of the running path. The first stacker crane 1A (the second stacker crane 1B) traverses the running path between the first doorway 6A (the second doorway 6B) and a position near the second doorway 6B of the other stacker crane, namely, the second stacker crane 1B.

The stacker cranes 1A and 1B run and carry out cargo working operation according to instructions given thereto as to objective positions and contents of cargo working operation by a host controller 8 installed on the floor.

The stacker cranes 1A and 1B are provided respectively with a first collision avoidance system 10A and a second collision avoidance system 10B.

The constitution of the collision avoidance systems 10A and 10B will be described hereinafter with reference to Fig. 2 showing the first collision avoidance system 10A of the first stacker crane 1A, and Fig. 3 showing the second collision avoidance system 10B of the second stacker crane 1B, As obvious from Fig. 2 and 3, the two collision avoidance systems 10A and 10B are the same in constitution, and hence only the first collision avoidance system 10A of the first stacker crane 1A will be described with reference to Fig. 2.

The first collision avoidance system 10A comprises a light projector 20 which projects light in a horizontal light beam toward the second stacker crane 1B, a light receiver (semiconductor position detector) 30 which receives light reflected by the second stacker crane 1B, and a detecting circuit 40 which receives signals from the light receiver 30 and a running mode control unit 90 and gives alarm signals ALM1 and ALM2 to the running mode control unit 90 to prevent the collision of the stacker cranes 1A and 1B when there is the possibility of collision between the first stacker crane 1A and the second stacker crane 1B. The light projector 20, the light receiver 30, the detecting circuit 40 and the running mode control unit 90 are provided on the first stacker crane 1A.

The running mode control unit 90 controls the running mode of the first stacker crane 1A and is of a known constitution. The running mode control unit 90 detects the present running speed Vd of the first stacker crane 1A to regulate the running speed of the stacker crane 1A at a target running speed, by using, for example, a pulse encoder, not shown, which rolls along the rail 2 and generates pulses. The running mode control unit 90 counts the pulses generated by the pulse encoder to detect the distance of the first stacker crane 1A from the home position 2A of the same at one end of the running path. The home position 2B of the

second stacker crane 1B is at the other end of the running path. The running mode control unit 90 is capable of gradually reducing the target running speed by an ordinary stopping means and changing the target running speed to zero and actuating a mechanically brake by an emergency stopping means to stop the first stacker crane 1A. The running mode control unit 90 gives signals representing the present running speed Vd and present running direction Vf of the first stacker crane 1A. The running mode control unit 90 determines the running direction Vf on the basis of the pulse encoder or an instruction given thereto from the host controller 8. The running direction Vf is positive when the first stacker crane 1A is running away from the home position 2A and is negative when the first stacker crane 1A is running toward the home position 2A. Upon the reception of the alarm signals ALM1 and ALM2, the running mode control unit 90 starts the stacker crane stopping operation.

The light projector 20 projects a light beam on a diffusion plate 3 attached to the frame of the second stacker crane 1B. The diffusion plate 3 is formed of a polished metallic plate provided with hairlines for irregular reflection.

The light receiver 30 comprises a lens 31 and a semiconductor position detecting element 32 and detects the position of a light spot of the incident light on the

semiconductor position detecting element 32. In Fig. 2, indicated at Y is the distance between the optical center of the lens 31 and the optical axis of the light projector 20.

When the second stacker crane 1B is at a position Ab_1, the reflected light is focused by the lens 31 on the detecting element 32 at a position B11. When the second stacker crane is at a position $1B_2$, the reflected light is focused at a position B12 on the detecting element 32. The position on the detecting element 32 at which the reflected light is focused is detected by the detecting circuit 40.

Since the distance Y between the lens 31 and the light projector 20, and the distance between the lens 31 and the detecting element 32 are known, the incident angle of the reflected light on the detecting element can be determined by detecting the spot position on the detecting element 32 where the incident light is focused, and thereby the distance Ls between the first stacker crane 1A and the second stacker crane 1B (hereinafter referred to "relative distance Ls") can be determined. That is the relative distance Ls is determined on the principle of triangulation.

The detecting element 32 has two output terminals A and B. The respective outputs at the output terminals A and B are dependent on the spot position on the detecting element 32. The distance Ls' between the output terminal B and the spot position can be determined by dividing the output

at the output terminal B by the sum of the respective outputs at the terminals A and B (A/(A + B)), and thereby the incident angle is determined to determine the relative distance Ls between the two stacker cranes 1A and 1B.

This light receiver 30 and the procedure for determining the spot position have previously been known. Generally, a range finder of such a constitution is called a semiconductor position detector.

The constitution of the detecting circuit 40 will be described hereinafter with reference Fig. 4.

The two outputs A and B of the detecting element 32 are amplified by amplifiers 41 and 42 and are converted into digital signals 43a and 44a by analog-to-digital converter (hereinafter designated as A/D converter) 43 and 44, respectively.

A microcomputer 50 comprises a random access memory (RAM) 51 for storing the digital signals 43a and 44a, a read-only memory (ROM) 52 storing basic information for avoiding collision, and a central processing unit (CPU) 53 for processing the data stored in the RAM 51 according information stored in the ROM 52 and for controlling associated devices. Indicated at 54 is a clock pulse generating circuit and at 55 is an input-output interface (I/O interface). The I/O interface 55 receives a running speed signal Vd and a running direction signal Vf from the running mode

control unit 90. An alarm signal ALM1 or an alarm signal ALM2 is given through the I/O interface 55 to the running mode control unit 90 when there is the danger of collision between the first stacker crane 1A and the second stacker crane 1B. The light projector 20 is controlled by a control unit 58. The running mode control unit 90 comprises a microcomputer.

Thus, the collision avoidance systems 10A and 10B detect the relative distance Ls and stops the associated stacker crane when the relative distance Ls is smaller than a predetermined distance. To avoid collision, a distance through which the stacker crane running at a running speed will run, namely, a brake stopping distance, must be determined on the basis of the respective running speeds and the respective running directions of the two stacker cranes. The running speed and running direction of the other stacker crane can be obtained through the host controller 8. However, in this embodiment, the running speed and running direction of the other stacker crane are estimated on the basis of the time-base variation of the relative distance Ls. Own running speed of one of the two stacker cranes detected for itself, the relative distance Ls and the alarm signals ALM1 and ALM2 are not given to the collision avoidance system of the other stacker crane.

The host controller 8 gives instructions to the stacker cranes to control the respective running modes of the stacker cranes so that collision between the two stacker cranes will not occur. However, it is possible that the issue of instructions by the host controller 8 is delayed, data is miscalculated, or the running mode control unit 90 or other device malfunctions. Accordingly, in this embodiment, the collision avoidance systems 10A and 10B are used as safety devices.

The collision avoidance systems 10A and 10B determines the relative distance Ls, and stops the associated stacker crane in case there is the possibility of collision. In some cases, the stacker cranes need not be stopped. Such a case will be described hereinafter.

Fig. 5 shows various kinds of combination of the respective running speeds and running directions of the two stacker cranes 1A and 1B, in which the direction of each arrow indicates the running direction of the stacker crane, and the length of each arrow indicates the running speed of the stacker crane. For example, in Case No. 1, the stacker cranes 1A and 1B are running toward each other and the running speed of the first stacker crane is greater than that of the second stacker crane. In Case No. 4, the stacker cranes 1A and 1B are running in the same direction. In Cases Nos. 2 and 5, the two stacker cranes 1A and 1B are

running at the same running speed. In Cases Nos. 3 and 7, the second stacker crane 1B is stopped, which is indicated by a dot. In cases indicated by a mark X, the collision avoidance system does not provide any stopping instruction, namely, the alarm signal ALM 1 or ALM2. Characters in the cases indicated by the mark X are step numbers corresponding to those where a decision is made to put the mark X in a control program shown in Fig. 6.

Reasons for putting the mark X to the case will be described hereinafter.

Cases Nos. 3b and 7a:

The first stacker crane 1A is stationary. The stacker crane is stopped either by an instruction issued by the host controller 8 (in a standby state) or by the action of the collision avoidance system. In the former case, it is convenient to maintain the stacker crane in a ready-to-run state for the next cargo working operation. Accordingly, any stopping instruction is provided. The running mode control unit 90 discriminates the stopping state between the former case and the latter case. In the latter case, the stacker crane is stopped by the action of the collision avoidance system, and hence the stacker crane needs to be held stopped. When the relative distance increases as the other stacker crane runs, while the stacker crane is stopped as in the case 7a, the stacker crane is started again.

Cases Nos. 4b, 5b, 6b, 7b, 8a and 8b:

The stacker crane is running away from the other stacker crane. In these cases, the two stacker cranes never collide with each other when the two stacker cranes continue to run. Accordingly, no stopping instruction is provided. The two stacker cranes running away from each other means the stacker crane on the right-hand side runs to the right and the stacker crane on the left-hand side runs to the left. That is, as mentioned with reference to Fig. 1, the stacker cranes run toward the respective home positions. Therefore, the running direction of the stacker crane can be recognized from the examination of the running instruction or from a decision as to whether or not the distance of the stacker crane from the home position thereof is increasing.

Case 6a:

In this case the distance between the two stacker cranes increases, and hence the stacker cranes need not be stopped. This case can be discriminated from a decision in step S9 of Fig. 6 as to whether the relative speed Vs obtained in step S7 is positive or whether the same is negative.

Case 5a:

In this case the distance between the two stacker cranes remains constant, that is, the two stacker cranes are running respectively at equal running speeds. This case can

be discriminated from a decision in step S9 of Fig. 6 as to whether the relative speed Vs obtained in step S7 is zero or whether the same is greater than zero. In the procedure shown in Fig. 6, the respective functions of the collision avoidance systems are not interrupted to ensure collision avoidance in such a case as the case 5a.

A normal running pattern of the stacker crane will be described hereinafter with reference to Fig. 17. In the moving stacker crane toward a target position, the stacker crane is accelerated at a fixed rate (section I), then the stacker crane runs at a constant speed (section II), then the stacker crane is decelerated at a fixed rate (section III), then the stacker crane runs at a fixed low speed (section IV), and then the brake is applied to stop the stacker crane. The running speed of the stacker crane in the section II is dependent on the distance Lx between the starting position and the target position. The running mode in the section IV in which the stacker crane runs at a fixed low speed is designated as creep running. Thus, the running speed of the stacker crane is varied with the sections.

When the alarm signal ALM1 or ALM2 is provided while the stacker crane is being accelerated, acceleration of the stacker crane is stopped at time P_1, then the stacker crane runs at a fixed speed corresponding to the running speed of

the stacker crane at the time P_1 for a short time T_2 from the time P_1 when the acceleration is stopped, and then the stacker crane is decelerated to avoid the action of shocks attributable to the direct conversion from acceleration to deceleration on the loads on the stacker crane. Likewise, in decelerating the stacker crane in response to the alarm signal ALM1 or ALM2 provided at the start of running at a constant speed, the stacker crane is allowed to run also for the time T_2.

The operation of the collision avoidance systems 10A and 10B will be described hereinafter with reference to Fig. 6. Since the first stacker crane 1A and the second stacker crane 1B are the same in operation, only the operation of the first stacker crane 1A will be described herein.

The procedure shown in Fig. 6 is started periodically in a timer interrupt mode.

In step S1, the relative distance Ls, namely, the distance between the first stacker crane 1A and the second stacker crane 1B is determined from digital signals 43a and 44a appeared respectively at the terminals A and B of the detecting element 32. In determining the relative distance Ls, first a spot distance Ls', namely the distance between the spot position on the detecting element 32 and the output terminal B of the detecting element is calculated by using an expression:

Ls' = 43a/(43a + 44a) .... (1)

The spot distance Ls' may be calculated by using other known calculus.

Then, the incident angle of the reflected light on the detecting element 32 is determined on the basis of th spot distance Ls', and then the relative distance Ls is determined. Since the relation between the relative distance Ls and the spot distance Ls' is nonlinear as shown in Fig. 9, the relative distance Ls is determined by using the spot position Ls' as a parameter according to the relation between the relative distance Ls and the spot distance Ls' tabulated in Fig. 10. The relative distance Ls thus determined is stored in the RAM 51.

Then, In step S3, a signal representing the running direction Vf provided by the running mode control unit 90 is examined to decide whether or not the first stacker crane 1A is running toward the home position. When the stacker crane is running toward the home position, the control program jumps to step S33. When the first stacker crane 1A is running toward the second stacker crane.

When the first stacker crane 1A is running toward the second stacker crane 1B, relative speed Vs, namely, the running speed of the first stacker crane 1A relative to the second stacker crane 1B, is calculated in step S5 by using an expression:

$$Vs = (Ls_{-1} - Ls)/T_1 \quad \text{........} \quad (2)$$

where Ls_{-1} is the relative distance obtained by the preceding process, Ls is the relative distance obtained by the succeeding process, and T_1 is an interval for detecting the relative distance Ls.

In step S7, it is decided whether or not the relative speed Vs is less than zero. When the second stacker crane 1B is running at a running speed higher than that of the first stacker crane 1A and hence the relative distance is increasing, the relative speed Vs is less than zero (Cases Nos. 6a and 7a), the relative speed Vs is less than zero. Then, in step S9, it is decided whether or not the running speed Vd of the first stacker crane 1A is zero. When the decision in steps S9 is No (Case No 7a), the control program jumps to step S33. When the decision in step S9 is Yes (Case No. 6a), namely, the running speed of the first stacker crane is zero, the relative speed Vs is considered to be equal to the running speed Ve of the second stacker crane 1B in step S10. In this case, the relative speed Vs is a negative value. When the excess distance Lk between the stacker cranes 1A and 1B increases after the first stacker crane 1A has been stopped by the collision avoidance system 10A, the stopping state of the first stacker crane 1A is cancelled. The excess distance Lk is calculated in step S21.

When the relative speed Vs is greater than zero, the running speed Ve of the second stacker crane 1B is determined in step S11 by using an expression:

$$Ve = |Vs| - Vd \qquad \text{......... (3)}$$

where Vd is a positive value provided by the own running mode control unit 90.

Suppose that a deceleration instruction is issued to avoid collision. The respective brake stopping distances Ld and Le of the stacker cranes 1A and 1B are calculated in steps S13 and S15 by using expressions:

$$Ld = Vd^2/2\beta d \qquad \text{........ (4)}$$

$$Le = Ve^2/2\beta e \qquad \text{........ (5)}$$

where βd is the deceleration of the first stacker crane 1A, and βe is the deceleration of the second stacker crane 1B.

Since the stacker crane is allowed to run at a constant speed for the time T_2 as shown in Fig. 17, when an instruction to stop is issued during acceleration, the actual values of the stopping distances Ld and Le are greater than the stopping distances Ld and Le calculated by using the expressions (4) and (5), respectively. Therefore, the respective actual stopping distances of the first stacker crane 1A and the second stacker crane 1B are determined by adding constant-speed running distances, namely, distances through which the first stacker crane 1A and the second stacker crane 1B run respectively at fixed running speeds

for the time T_2, T_2 x Vd and T_2 x Ve respectively to the calculated stopping distances Ld and Le.

The values of K1 (step S23) and K2 (step S27) in Fig. 6 are determined by adding the constant-speed running distances T_2 x Vd and T_2 x Ve as fixed values.

However, since such a method of determination is inaccurate, it is possible to make the collision avoidance systems decide whether or not both the stacker cranes 1A and 1B are being accelerated and to add the respective constant-speed running distances respectively to the brake stopping distances Ld and Le.

In step S17, the running direction of the second stacker crane 1B is decided by deciding whether or not the running speed Ve of the second stacker crane 1B is greater than zero. When the stacker cranes 1A and 1B are running in opposite directions, the running speed Ve of the second stacker crane 1B is greater than zero (Cases Nos. 1a, 1b, 2a, 2b and 3a). In such a case, the excess distance Lk is calculated in step S19 by using an expression:

$$Lk = Ls - (Ld + Le) \quad \ldots\ldots\ldots (6)$$

When the stacker cranes 1A and 1B are running in the same direction (Cases Nos. 4a and 5a), the running speed Ve is less than zero. In such a case, the excess distance Lk is calculated in step S21 by using an expression:

$$Lk = Ls - (Ld - Le) \quad \ldots\ldots\ldots (7)$$

As shown in Fig. 11, the relative distance Lk is a distance remaining between the first stacker crane 1A and the second stacker crane 1B after the stacker cranes 1A and 1B have been stopped by starting the stopping action when the first stacker crane 1A is separated from the second stacker crane 1B by the relative distance Ls. In step S23, it is decided whether or not the excess distance Lk is greater than the normal distance K1. When the excess distance Lk is smaller than the normal distance K1, collision is possible. Therefore, the alarm signal ALM1 is given to the running mode control unit 90 in step S25 to stop the first stacker crane 1A. When the excess distance Lk is smaller than the normal distance K2 (step S27), collision is possible. Therefore, the alarm signal ALM2 is given to the running mode control unit 90 in step S29 to stop the first stacker crane 1A.

The normal values K1 and K2 are determined taking into consideration errors in measuring the relative distance Ls, the constant-speed running distances, the running distances during the interval between the successive detection cycles, errors in stopping positions, and the position of the reflector of the light receiver 30, and K1 is smaller than K2.

The acceleration of the stacker crane corresponding to the alarm signal ALM1 is greater than that corresponding to the alarm signal ALM2. When the alarm signal ALM1 is given,

the running mode control unit 90 provides an instruction to reduce the running speed to zero and actuates a mechanical brake. When the alarm signal ALM2 is given, the running mode control unit 90 executes a normal stopping action. The stacker cranes are decelerated respectively at the decelerations βd and βe (which are the same as the deceleration in the decelerating section of Fig. 17) in response to the alarm signal ALM2. When the excess distance Lk is small, the alarm signal ALM1 is given to the running mode control unit 90.

The control program shown in Fig. 6 is executed periodically every predetermined interval even when the stopping action is started in response to the alarm signal ALM1 or ALM2. Accordingly, the alarm signals ALM1 and ALM2 are cancelled when the excess distance Lk exceeds the normal distance K2 after the stacker crane has been stopped (steps S27 and S31).

Control operation succeeding the cancellation of the alarm signals ALM1 and ALM2 will be described afterward.

The present relative distance Ls determined in the succeeding detecting cycle is transferred to the storage area of the previous relative distance Ls_{-1} determined in the preceding detecting cycle in the RAM 31 in step S33.

Fig. 7 shows a control program to be executed by the running mode control unit 90 upon the reception of the alarm

signal ALM1 or ALM2. Upon the reception of the alarm signal ALM1 or ALM2, the running mode control unit 90 decides whether or not the first stacker crane 1A is standing by, namely, whether or not the first stacker crane 1A is stopped awaiting the next cargo working instruction, in step S41. When the stacker crane 1A is not standing by, namely, when the first stacker crane 1A is running or is in stopping operation in response to the alarm signal ALM1 or ALM2, the stopping operation according to the alarm signal ALM1 or ALM2 is executed in step S43.

When the running speed Vd of the first stacker crane 1A is zero, timing operation is started in step S47. Then, it is decided in step S49 whether or not predetermined time has passed after the first stacker crane 1A has been stopped in response to the alarm signal ALM1 or ALM2. When the decision in step S49 is Yes, a signal is given to the host controller 8 in step S51.

Upon the reception of the signals from both the stacker cranes 1A and 1B in step S51, the host controller 8 provides an instruction directing the manual operation of the stacker cranes 1A and 1B. Such a manual operation is carried out to restore the normal operating condition of the stacker cranes 1A and 1B when the two stacker cranes are stopped by the operation of the collision avoidance systems 10A and 10B in the Cases Nos. 1a, 1b, 2a and 2b.

Fig. 8 is a subroutine to be executed in step S43 of the control program shown in Fig. 7. In step S55, it is decided whether or not the first stacker crane 1A is being accelerated. When the decision in step S55 is Yes, the stopping operation is started in step S61 after the present running speed has been maintained for the time T_2 in step S59. On the other hand, when the decision in step S55 is NO, it is decided in step S63 whether or not the time T_2 has passed after the start of the constant-speed running. When the decision in step S63 is No, the constant-speed running is maintained for the rest of the time, and then the stopping operation is started (steps S65 and S67).

Thus, when the relative distance Ls is reduced below the predetermined distance, the running stacker crane or cranes are stopped to avoid collision. Since the relative distance Ls of the first stacker crane 1A and the running speed of the second stacker crane 1B are detected by the own collision avoidance system 10A of the first stacker crane 1A, the collision avoidance system 10A functions satisfactorily as a safety device. Since the relative distance Ls of the first stacker crane 1A at which the stopping operation for stopping the first stacker crane 1A is started is varied according to the own running speed Vd of the first stacker crane 1A and the running speed Ve of the second stacker crane 1B, the stacker cranes 1A and 1B can run at higher

running speeds and the range of high-speed running is expanded.

Since any alarm signal is not generated while the first stacker crane 1A is running away from the second stacker crane 1B or is stopped, the degree of safety is enhanced and the deterioration of the cargo working efficiency can be prevented.

Although the invention has been described in terms of effects as a safety device, the present invention effectively improves the cargo working efficiency. Since a limit distance, namely, a critical distance where the stopping operation is to be started to avoid collision between the two stacker cranes, is determined on the basis of the respective running speeds of the two stacker cranes, the limit distance between the two stacker cranes can be reduced according to the reduction of the respective running speeds of the two stacker cranes, so that the cargo working efficiency is improved. For example, suppose that points indicated at XA and XB in Fig. 11 are the respective target positions of the first stacker crane 1A and the second stacker crane 1B for cargo working operation. When the two stacker cranes 1A and 1B are running at a comparatively low speed, the relative distance Ls at which the alarm signal ALM1 or ALM2 is generated is small. Therefore, neither the alarm signal ALM1 nor the alarm signal ALM2 is generated

even if the distance between the target positions XA and XB is small. Accordingly, the two stacker cranes 1A and 1B are allowed to run simultaneously respectively toward the target positions XA and XB, and thereby the cargo working efficiency is improved.

If the distance between the target positions XA and XB is smaller than the limit distance where the alarm signal is to be generated, the two stacker cranes 1A and 1B are stopped respectively before the target positions XA and XB. In such a case, one of the stacker cranes, for example, the second stacker crane 1B to the target position XB under the control of the host controller 8, and then the first stacker crane can be started to run to the right upon the start of the second stacker crane 1B to the right. Thus, the two stacker cranes can approach each other without actuating the collision avoidance systems, so that the cargo working efficiency is improved.

In this embodiment, it is possible to suspend the relative distance measuring operation of the collision avoidance system while the associated stacker crane is running toward the home position or while the same is standing by.

When the stacker cranes are operating at a high running speed, the alarm signal ALM1 or ALM2 must be generated while the relative distance Ls is comparatively large. In

this embodiment, the intensity of the reflected light decreases with increase in the relative distance Ls making the measurement of the relative distance Ls difficult. In this embodiment (Figs. 2 to 10), the running speed Ve of the second stacker crane is determined on the basis of the relative distance Ls by using the expression (2). However, in some cases, error in one of the relative distances Ls_{-1} and Ls is the upper limit of an allowable range of error and error in the other relative distance in the lower limit of an allowable range of error, and since the difference between the relative distances Ls_{-1} and Ls is differentiated by time T_1, the relative speed Vs varies greatly between calculating cycles. That is, it is difficult to determine the true value of the relative speed Vs. Consequently, it is difficult to determine the running speed Ve of the second stacker crane 1B accurately in steps S10 and S11, and hence it is difficult to determine the stopping distance Ld of the second stacker crane 1B accurately in step S15 and the result of calculation varies with every computation. Accordingly, the alarm signals ALM1 and ALM2 are generated unnecessarily in steps S25 and S29 or the alarm signals ALM1 and ALM2 are not generated when necessary. The unnecessary generation of the alarm signals ALM1 and ALM2 can be obviated by increasing the normal distances K1 and K2. However, the increase of the normal distances K1 and K2 reduces the

distance through which the stacker cranes are allowed to run at a comparatively high running speed.

A collision avoidance system, in a second embodiment, according to the present invention will be described hereinafter with reference to Figs. 12 through 14. The second embodiment incorporates further improvements to solve those two problems in the first embodiment. Since the second embodiment is similar to the first embodiment, the second embodiment will be described in respect of parts which are different from those of the first embodiment. Since the respective collision avoidance systems 10A and 10B of stacker cranes 1A and 1B are the same in constitution, only the collision avoidance system 10A will be described herein.

First, improvements intended to obviate the erroneous operation of the collision avoidance system will be described. Referring to Fig. 12, a light receiver 60 is provided near a light projector 20 to receive light projected by the light projector 20 of the second collision avoidance system 10B. A wide-angle light projector 70 is provided near the light receiver 60 to project light obliquely to the second stacker crane 1B. The wide-angle light projector 70 emits light in a wide angular range. Therefore, the wide-angle light projector 70 can apparently be regarded as a point light source by the light receiver 30 of the second stacker crane 1B. The wide-angle light projector 70 is of a

known type. The light receiver 60 may be of any time capable of detecting whether or not the light projector 20 of the second stacker crane 1B is emitting light. The light projector 20, the light receiver 60, the wide-angle light projector 70 and the light receiver 30 are disposed for triangulation. The respective capacities of the light projector 20 and the wide-angle light projector 70 are large enough to enable the reception of light projected by the light projector 20 and the wide-angle light projector 70 at a far distant position.

The light projector 20 projects light at predetermined intervals determined by a detecting circuit 40. Upon the reception of light, the light receiver 60 the wide-angle light projector 70 is made to emit light. The detecting circuit 40 gives a signal to the light projector 20 to make the light projector 20 project light, and processes only optical data provided by the light receiver 30 in a predetermined very short time as effective data. Since the wide-angle light projector 70 is provided on the second stacker crane 1B, the first stacker crane 1A is able to measure the relative distance even when the stacker cranes 1A and 1B are far distant from each other. Since the light projector 20 projects light intermittently and data provided by the light receiver corresponding to light received in the predetermined very short time is used as effective data, the

collision avoidance system is never caused to operate erroneously by other light sources.

To solve the latter problem in the first embodiment, in the second embodiment, the respective detecting circuits 40 of the stacker cranes 1A and 1B are provided respectively with optical space transmitters 80. The respective optical space transmitters 80 of the first stacker crane 1A and the second stacker crane 1B are disposed opposite to each other for optical data communication therebetween. When instructed by the detecting circuit 40, the optical space transmitter 80 of the first stacker crane 1A modulates the running speed Vd' of the first stacker crane 1A into an optical signal and transmits the optical signal to the optical space transmitter 80 of the second stacker crane 1B. The optical space transmitter 80 also receives an optical signal representing the running speed Ve' of the second stacker crane 1B from the optical space transmitter 80 of the second stacker crane 1B and gives a signal corresponding to the optical signal to the associated detecting circuit 40. The optical space transmitters 80, namely, the optical data transmission techniques are well known.

The signal given from the detecting circuit 40 to the optical space transmitter 80 includes data representing the running speed Vd' and running direction Vf of the first stacker crane 1A. The sign of the running speed Vd' is

negative when the first stacker crane 1A is running toward its home position 2A, and is positive when the same is running away from the home position 2A. The signal received from the optical space transmitter 80 of the second stacker crane includes data representing the running speed Ve' and running direction of the second stacker crane 1B. The running speed Vd' of the first stacker crane 1A is measured at predetermined intervals and is sent out through the optical space transmitter 80. The optical space transmitter 80 receives signals representing the running speed Ve' of the second stacker crane 1B at predetermined intervals.

The light projector 20, the light receivers 30 and 60, the wide-angle light projector 70, the optical space transmitter 80 and the detecting circuit 40 are integrated into a single unit.

The operation of the collision avoidance system thus constituted will be described with reference to Fig. 14 only with respect to steps which are different from those of Fig. 6. In step S1, the relative distance Ls of the first stacker crane 1A is measured through calculation by intermittently actuating the light projector 20. In step S2a, the running speed Vd' of the first stacker crane 1A is sent out through the optical space transmitter 80 and , in step S2b, the running speed Ve' of the second stacker crane 1B is detected. In step S5a, the relative speed Vs is obtained

through calculation on the basis of the running speed Vd' and the running speed Ve' of the second stacker crane 1B by using an expression:

$$Vs = Vd' + Ve' \qquad \text{........ (8)}$$

This control program does not have steps corresponding to steps S10 and S11 of the control program of Fig. 6. The rest of the steps of this control program are the same as those of the control programs of Fig. 6.

Thus, the stacker cranes 1A and 1B each is able to detect the running speed and running direction of the other accurately. Therefore, there never occurs the unnecessary generation and failure in generation of the alarm signals ALM1 and ALM2.

Although the foregoing embodiments use light for measuring distance, microwaves may be used for the same purpose.

Fig. 15 shows the constitution of a distance measuring unit employed in a collision avoidance system, in a third embodiment, according to the present invention. This distance measuring unit uses a microwave for detecting distance. A microwave signal modulated by an oscillator 134 and transmitted through an antenna 132 from the collision avoidance system of a first stacker crane 1A is reflected by a reflecting plate 131 provided on a second stacker crane 1B. The reflected microwave signal is received through the

antenna 132. Then, beats as shown in Fig. 16 are produced due to the phase difference between the transmission microwave signal and the reception microwave signal. In Fig. 16, a solid line indicates the waveform of the transmission microwave signal, a broken line indicates the waveform of the reception microwave signal, fo is a center frequency, fb is a beat frequency, fr is a modulating frequency, Tr is a modulating period, Δf is the maximum frequency deviation, Δt is the time difference between the transmission microwave signal and the reception microwave signal, and $\bar{f}b$ is the average beat frequency.

As well known, the average beat frequency is in directly proportion to the distance between the antenna 132 and the reflecting plate 131 of the other distance measuring unit. That is,

$$\Delta t = 2R/C \qquad \text{........ (10)}$$

where R is the distance between the antenna and the reflecting plate of the other distance measuring unit, C is the propagation velocity of radio waves.

From Fig. 16,

$$\bar{f}b/\Delta t = 2\Delta f/Tr = 2 \cdot \Delta f \cdot fr \qquad \text{........ (11)}$$

Therefore,

$$R = C \cdot fb/4 \cdot \Delta f \cdot fr \qquad \text{........ (12)}$$

Only the beat signal is extracted by a phase correcting circuit 135 and a differential amplifier 136. Since a

signal thus obtained is a frequency signal, the frequency is converted into a voltage signal, namely, an analog signal, by a frequency-to-voltage (F/V) converter 137. The output voltage signal of the F/V converter 137 is converted into a digital signal by an A/D converter 138, and then the digital signal is applied to a microcomputer 139. The microcomputer 139 adds the output signals of the A/D converter 138 provided in a period from time when the output of the A/D converter 138 is zero to time when the output of the A/D converter 138 becomes zero again, and then divides the sum of the output signals of the A/D converter 138 by the number of data to obtain the average beat frequency representing the distance.

The distance between the two mobile objects, namely, the two stacker cranes, can be measured by other method, such as a method using the Doppler effect, and the distance may be calculated by the host controller 8 instead of the microcomputer 139.

When the mobile objects circulate along an endless running path instead of traversing on a finite running path, the sign of the own running direction is positive and the sign running direction of the preceding mobile object is negative, and hence the running direction of the mobile objects need not be detected.

It is also possible to control the respective running modes of the two mobile objects by the host controller 8 so that the two mobile objects will not collide with each other by using signals representing the respective present positions detected by the pulse encoders, running speeds and running directions of the two mobile objects.

Although the invention has been described in its preferred forms with a certain degree of particularity, obviously many changes and variations are possible therein. It is therefore to be understood that the present invention may be practiced otherwise than specifically described herein without departing from the scope and spirit thereof.

CLAIMS

1. A method of avoiding the collision of mobile objects, comprising steps of:

determining the relative distance between two mobile objects;

determining the respective stopping distances of the two mobile objects through which the two mobile objects will run, respectively, after stopping operation for stopping the two mobile objects is started while the two mobile objects are running respectively at certain running speeds; and

giving alarm signals respectively for stopping the two mobile objects to the two mobile objects when the sum of the respective stopping distances of the two mobile objects is smaller than a distance determined on the basis of the relative distance between the two mobile objects.

2. A method of avoiding the collision of mobile objects, comprising steps of:

determining the running speed of one of two mobile objects, the running speed of the other mobile object, and the relative distance between the two mobile objects;

determining the respective stopping distances of the two mobile objects through which the two mobile objects will run, respectively, after stopping operation for stopping the two mobile objects is started while the two mobile objects

are running respectively at certain running speeds and in certain directions; and

giving alarm signal to one of two mobile objects for reducing speed of the mobile object when the sum of the respective stopping distances of the two mobile objects is smaller than the sum of the relative distance between the two mobile objects and a predetermined distance.

3. A method of avoiding the collision of mobile objects comprising steps of;

determining the relative distance of one of two mobile objects by a detecting device mounted thereon with respect to the other mobile object;

transmitting signals respectively representing the running speed and running direction of the former mobile object to the latter mobile object by an optical space transmitter;

receiving signals respectively representing the running speed and running direction of the latter mobile object and transmitted by the optical space transmitter of the latter mobile object, by the optical space transmitter of the former mobile object;

determining the respective stopping distances of the two mobile objects through which the two mobile objects will run, respectively, when stopping operation is started while

the two mobile objects are running respectively at certain running speeds and in certain running directions; and

giving alarm signals respectively to the two mobile objects to decelerate the two mobile objects when the sum of the two stopping distances is smaller than a distance determined on the basis of the relative distance.

4. A method of avoiding the collision of mobile objects comprising steps of:

determining the relative distance between two mobile objects;

determining the respective stopping distances of the two mobile objects through which the two mobile objects will run, respectively, when stopping operation is started while the two mobile objects are running respectively at certain running speeds in certain running directions;

determining the difference between the sum of the two stopping distances and the relative distance between the two mobile objects; and

giving a first signal to each of the two mobile objects to brake the mobile object at a first deceleration when the difference between the sum of the two stopping distances and the relative distance between the two mobile objects is smaller than a first normal distance, or giving a second signal to each of the two mobile objects to brake the mobile object at a second deceleration lower than the first

deceleration when the difference between the sum of the two stopping distances and the relative distance between the two mobile objects is greater than the first normal distance and smaller than a second normal distance greater than the first normal distance.

5. A method of avoiding the collision of mobile objects, comprising steps of:

determining the relative distance of one of two mobile objects with respect to the other mobile object by a detecting device mounted thereon;

determining the running speed of the latter mobile object on the basis of the time-base variation of the relative distance, and the running speed of the former mobile object;

determining the respective stopping distances of the two mobile objects through which the two mobile objects will run, respectively, when stopping operation is started while the two mobile objects are running respectively at certain running speeds and in certain running directions;

giving alarm signals respectively for decelerating the two mobile objects respectively to the two mobile objects when the sum of the two stopping distances is smaller than a distance determined on the basis of the relative distance.

6. A collision avoidance system for avoiding the collision of two mobile objects, associated with one of the two mobile objects, comprising:

first means for determining the relative distance between the associated mobile object and the other mobile object;

second means for determining the running speed and running direction of the other mobile object;

third means for determining the respective stopping distances of the two mobile objects through which the two mobile objects will run, respectively, when stopping operation is started while the two mobile objects are running respectively at certain running speeds and in certain running directions; and

fourth means for giving alarm signals for decelerating the associated mobile object to the associated mobile object when the sum of the respective stopping distances of the two mobile objects is smaller than a distance determined on the basis of the relative distance.

7. A collision avoidance system for avoiding the collision of two mobile objects, according to Claim 6, wherein the alarm signals provided by said fourth means are a first signal and a second signal, said fourth means determines the difference between the sum of the stopping distances and the relative distance, the fourth means provides

the first signal when the difference is smaller than a first normal distance, and the fourth means provides the second signal when the difference is greater than the first normal distance and is smaller than a second normal distance greater than the first normal distance.

8. A collision avoidance system for avoiding the collision of mobile objects, according to Claim 6, wherein said first means includes a detector which projects a detecting medium on the other mobile object and detects the reflected detecting medium reflected by the other mobile object, and said relative distance is determined on the basis of data provided by the detector.

9. A collision avoidance system for avoiding the collision of mobile objects, according to Claim 6, wherein said third means has input terminals respectively for receiving signals representing the running speed and running direction of the associated mobile object.

10. A collision avoidance system, for avoiding the collision of mobile objects, according to Claim 7, wherein said fourth means has a first output terminal through which said first signal is provided, and a second output terminal through which said second signal is provided.

11. A collision avoidance system for avoiding the collision of mobile objects, associated with one of the two mobile objects, comprising:

a light projector which projects light in one direction;

a light receiver comprising semiconductor position detecting element capable of detecting a light reception position corresponding to the incident angle of light incident thereon, and disposed with the light receiving surface thereof directed substantially in the light projecting direction of the light projector;

an optical space transmitter capable of transmitting and receiving optical data and disposed with the transmission-reception surface directed substantially in the same direction as the light projector;

first means for controlling the optical space transmitter so as to transmit data representing the running speed and running direction of the associated mobile object;

second means for detecting the relative distance between a light source projecting light to the semiconductor position detecting element and the semiconductor position detector by detecting the light reception position on the semiconductor position detecting element;

third means for determining the stopping distance through which the associated mobile object will run when stopping operation is started while the associated mobile object is running at a certain running speed in a certain running direction;

fourth means for determining the stopping distance through which the other mobile object will run when stopping operation is started while the other mobile object is running at a certain running speed and in certain running direction; and

fifth means for giving an alarm signal for decelerating the associated mobile object to the associated mobile object when the sum of the respective stopping distances of the associated mobile object and the other mobile object is smaller than a distance determined on the basis of the relative distance.

12. A collision avoidance system for avoiding the collision of mobile objects, according to Claim 11 further comprising:

a second light receiver disposed with the light receiving surface thereof directed in the light projecting direction of said light projector; and

a wide-angle light projector capable of projecting light in an angular range wider than that of said light projector in substantially the same direction as said light projector;

wherein said light receiver is disposed with the light receiving surface directed in the light projecting direction of the wide-angle light projector.

13. A collision avoidance system for avoiding the collision of mobile objects, according to Claim 12, wherein said light projector is controlled by sixth means so as to project light at predetermined intervals, said wide-angle light projector is allowed to project light for a short time when said second light receiver receives light, and said second means accepts data provided by said light receiver corresponding to light received by said light receiver in a predetermined time after an instruction directing said light projector to project light has been given to said light projector as effective data.

14. A collision avoidance system for avoiding the collision of two mobile objects, associated with one of the two mobile objects, comprising:

a light projector which projects light in one direction;

a light receiver comprising a semiconductor position detecting element capable of detecting a light reception position corresponding to the incident angle of light incident thereon and disposed with the light receiving surface thereof substantially in the light projecting direction of the light projector;

first means for detecting the relative distance between a light source from which the semiconductor position detecting element receives light and the semiconductor

position detecting element by detecting the light reception position on the semiconductor position detecting element;

second means for determining the running speed and running direction of the other mobile object on the basis of the variation of the relative distance detected by the first means;

third means for determining a stopping distance through which the associated mobile object will run when stopping operation is started while the associated mobile object is running at a certain running speed in a certain running direction;

fourth means for determining a stopping distance through which the other mobile object will run when stopping operation is started while the other mobile object is running at a certain running speed and in a certain running direction; and

fifth means for giving an alarm signal for decelerating the associated mobile object to the associated mobile object when the sum of the respective stopping distances of the associated mobile object and the other mobile object is smaller than a distance determined on the basis of the relative distance.

15. A mobile object comprising:

first means for detecting the relative distance between the associated mobile object and another mobile object;

second means for detecting the running speed and running direction of another mobile object;

third means for determining stopping distances through which the associated mobile object and another mobile object will run, respectively, when stopping operation is started while the associated mobile object and another mobile object are running respectively at certain running speeds and in certain running directions;

fourth means having an alarm signal output terminal, for providing an alarm signal to decelerate the associated mobile object when the sum of the respective stopping distances of the associated mobile object and another mobile object is smaller than a distance determined on the basis of the relative distance; and

a running mode control unit for controlling the running mode of the associated mobile object, connected to the alarm signal output terminal of the fourth means to receive the alarm signal from the fourth means.

16. A mobile object according to Claim 15, wherein said first means, said second means, said third means and said fourth means and said running mode control unit are mounted thereon.

17. A cargo working system comprising two mobile objects which run on a single running path respectively within overlapping ranges, and are provided respectively with the collision avoidance systems as stated in Claim 8 with said detector directed toward the other mobile object, wherein the alarm signal output terminal of said fourth means of each mobile object is connected to the running mode control unit of the same mobile object.

18. A cargo working system comprising two mobile objects which run on a single running path respectively within overlapping ranges, and are provided respectively with the collision avoidance systems as stated in Claim 12 with said light projector, said light receiver, said second light receiver, said wide-angle light projector and said optical space transmitter directed toward the other mobile object, wherein the alarm signal output terminal of said fourth means of each mobile object is connected to the running mode control unit of the same mobile object.

19. A method of avoiding the collison of mobile objects substantially as hereinbefore described, with reference to the accompanying drawings.

20. A collision avoidance system for avoiding the collison of two mobile objects substantially as hereinbefore described, with reference to and as illustrated in the accompanying drawings.

21. A mobile object including collision avoidance means constructed and arranged to operate substantially as hereinbefore described, with reference to and as illustrated in the accompanying drawings.

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